2021 U.S. Department of Energy
Vehicle Technologies Office
Annual Merit Review

DISTRIBUTIONS OF REAL-WORLD VEHICLE TRAVEL

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PROJECT ID: VAN036

VTO Annual Merit Review
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This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline	Barriers addressed
• Project start: October 1, 2019 • Project end: September 30, 2022 • 53% complete (1.5 years of 3)	• "Fill gaps or deficiencies in the analysis toolset based on the best publicly available, up to date techno-economic assessments." (ISATT roadmap, 2018) • "Inconsistent data, assumptions, and guidelines." (FPITT roadmap, 2017)
Budget	**Partners**
• Total project funding: $450,000 (100% DOE share) • FY 2020: $150,000 • FY 2021: $150,000 • FY 2022: $150,000 (planned)	• Connections with researchers across several DOE labs: • LBNL, NREL, ORNL • Linkage with TCO project (VAN038)

Relevance

- **DOE VTO is interested in being able to compare economics of vehicle operation across multiple technologies in a balanced manner**
- Driving behavior is not homogenous, and using a single mileage schedule for all calculations related to lifecycle emissions, cost of ownership, and vehicle survivability does not yield a full understanding of fleet-wide fuel consumption.
- Vehicle choice models used for analysis and for policymaking strongly rely on assumptions about vehicle miles traveled (VMT) and vehicle lifetime.
- Optimal vehicle choices from a levelized-cost-of-driving standpoint may vary depending on differing use cases.
- New technologies are more likely to be useful to a subset of consumers before the whole market, e.g., a battery electric vehicle driven more intensively than the average may have an easier time reaching cost parity than a “typical” vehicle.

Approach – General

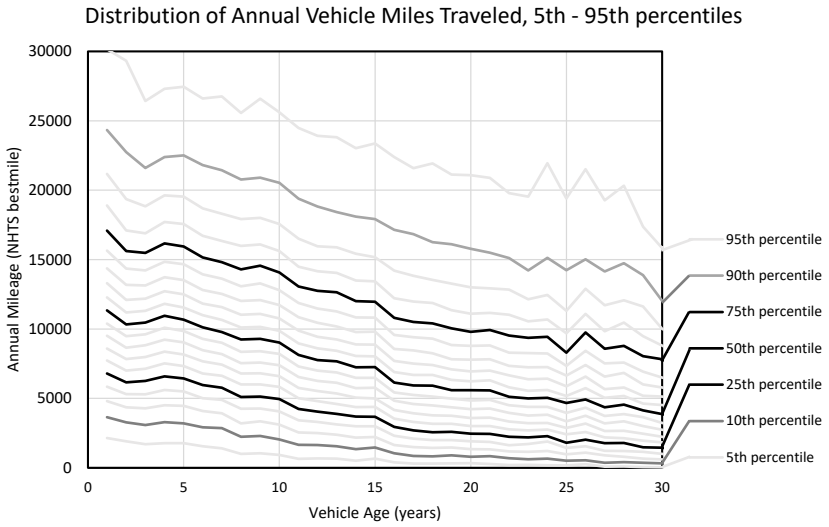
- This project will:
  - 1) quantify variations in vehicle miles traveled (VMT), considering vintage, vehicle characteristics, and demographic characteristics;
  - 2) quantify levelized cost of driving (LCOD) for vehicles with different use intensities;
  - 3) estimate how variations in VMT impact national-scale metrics such as fuel consumption and emissions, both for today's vehicles and potential future scenarios; and
  - 4) assess variations in vehicle survivability.
- All analyses will rely on empirical, real-world data for sales, registration, and VMT (where possible)
- Initial focus on light-duty vehicle (LDV) passenger vehicle fleet, shift focus to medium/heavy duty-vehicle (MHDV) commercial in later years

Approach – Milestones

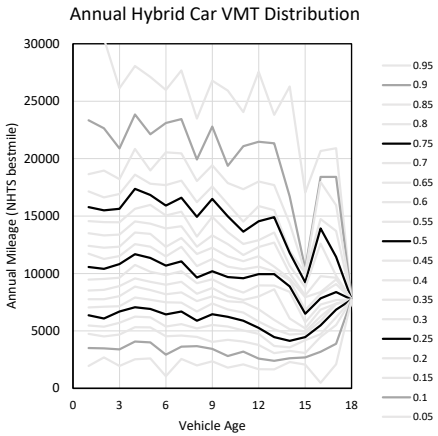
Tasks	FY2021 deliverables	FY2021				Status
		Q1	Q2	Q3	Q4	
Distribution of VMT	TRB Meeting submission: Distributions of VMT by household and vehicle characteristics			x		In progress
Levelized Cost of Driving (LCOD)	Comparison of LCOD for different use segments **(Go / No-go)**			x		In progress
Aggregate Fleet Metrics	Quantification of future national-level metrics with homogeneous fleet	x				Analysis complete
Vehicle Survivability	Methodology for scrappage as a function of VMT		x			Complete
	Technical Report: Analysis of scrappage as a function of vehicle characteristics and other metrics				x	In progress

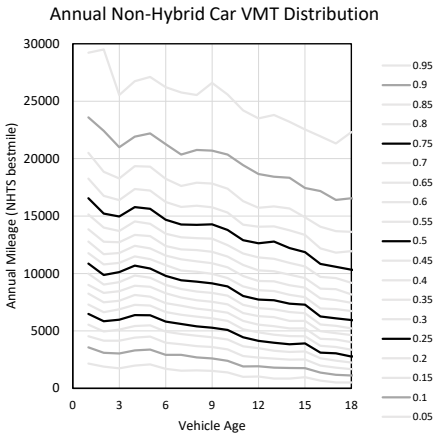
Technical Progress – VMT distributions

- Continued progress toward publication of results
- Broad range of VMT across all vehicles
  - Explored multiple disaggregations of this data, including urban/rural, car/truck, primary/secondary, and luxury/non-luxury



- Hybrid Electric Vehicles (HEV) do not show same characteristic shape as non-HEV for VMT as a function of age, maintaining a nearly flat VMT distribution at most percentiles for the first decade of use



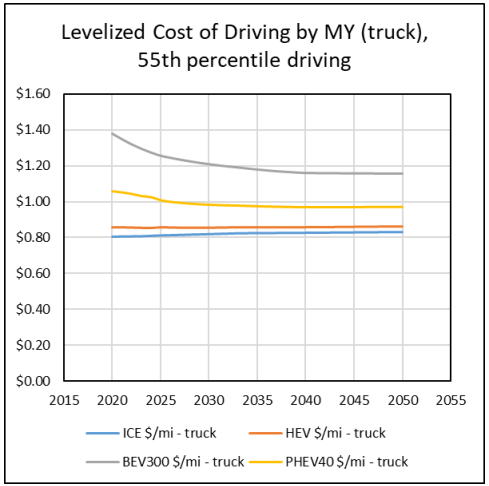


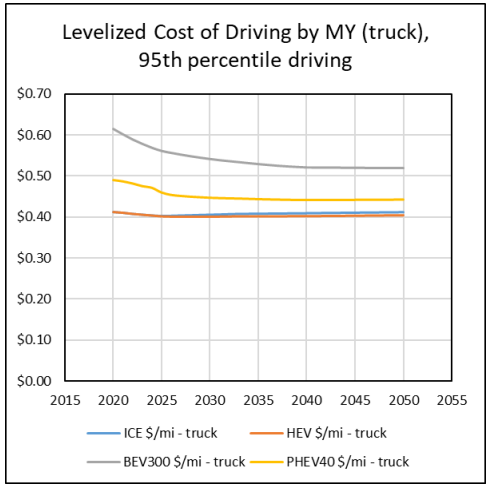
Technical Progress – Levelized Cost of Driving

- Contributed information to broader Total Cost of Ownership (TCO) project for comprehensive calculations for LDV and MHDV
- Simplified LCOD using cost of vehicle and fuel to highlight differences in vehicle efficiency
  - Equation accounts for purchase cost, fuel costs (over time), and a discount rate

$$\mathrm{LCOD} = \frac{\mathrm{Cost}_{veh} + \mathrm{Cost}_{fuel}}{\text{"Distance"}} = \frac{C}{\sum_{i=1}^{n} VMT_i \times (1+d)^{-i}} + \frac{\text{gas price}_i}{\text{mpg}}$$

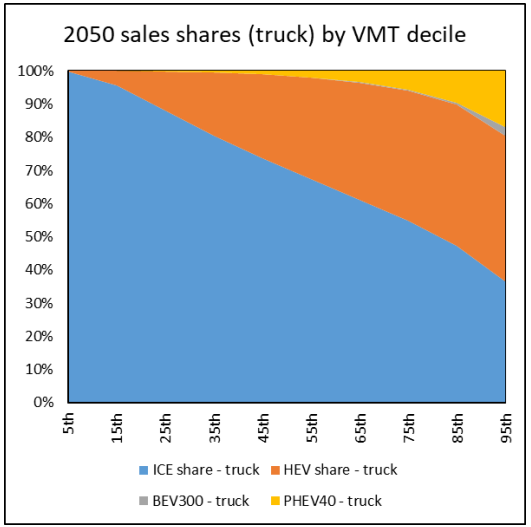
- Modeled vehicles at 55th and 95th percentiles of driving distance for 4 different powertrains
  - EIA's Annual Energy Outlook 2020 as the baseline for vehicle cost
  - 5-year analysis window (no residual value), 3% discount rate
- Alt-fuel powertrain vehicles closer to cost parity for higher driving distances





Technical Progress – Aggregate Fleet Metrics

- Generated simplistic vehicle sales model where probability of purchasing a car is proportional to e^{-kx} to input sales shares into VISION. Here k is a proportionality constant, and x is the cost of driving per mile (over the first five years of ownership)
- Much higher share for electric/electrified vehicles at higher driving distances, as these vehicles are more cost effective



- Comparing 2 scenarios:
  - A: constant sales shares by decile
  - B: varying sales shares by decile
- Scenario A, through 2050:
  - 9.45 quads energy, 0.13 quads electricity
- Scenario B, through 2050:
  - 8.95 quads energy, 0.24 quads electricity
- Heavier electrification in most intense segment leads to moderately lower energy consumption (-5.3%) and much higher LDV electricity charging (+80%)

Technical Progress – Survivability

- Identified correlations between different vehicle, demographic, and policy factors with vehicle age

	Number of vehicles	Average Age	Average MPG	% HEV/PEV	Annual Snowfall (in)	Registration fee (age 12)	Emissions Inspection	Safety Inspection	Fuel Price	Average VMT	Median Income
Number of vehicles	1.00	-0.40	0.42	0.49	-0.32	0.12	0.09	0.07	0.39	-0.18	0.07
Average Age	-0.40	1.00	-0.78	-0.27	-0.06	-0.01	-0.40	-0.48	-0.10	-0.18	-0.48
Average MPG	0.42	-0.78	1.00	0.64	0.01	0.06	0.52	0.36	0.41	0.06	0.55
% HEV/PEV	0.49	-0.27	0.64	1.00	0.02	0.35	0.40	0.03	0.80	-0.06	0.52
Annual Snowfall (in)	-0.32	-0.06	0.01	0.02	1.00	0.21	0.19	0.08	0.09	0.14	0.42
Registration fee (age 12)	0.12	-0.01	0.06	0.35	0.21	1.00	0.06	-0.32	0.39	0.11	0.39
Emissions Inspection	0.09	-0.40	0.52	0.40	0.19	0.06	1.00	0.37	0.31	-0.04	0.43
Safety Inspection	0.07	-0.48	0.36	0.03	0.08	-0.32	0.37	1.00	-0.14	-0.02	0.11
Fuel Price	0.39	-0.10	0.41	0.80	0.09	0.39	0.31	-0.14	1.00	-0.29	0.37
Average VMT	-0.18	-0.18	0.06	-0.06	0.14	0.11	-0.04	-0.02	-0.29	1.00	0.50
Median Income	0.07	-0.48	0.55	0.52	0.42	0.39	0.43	0.11	0.37	0.50	1.00

- Began development of bottom-up scrappage model based on levelized cost of driving
  - A vehicle will remain in use if it is economically sound to do so, and a vehicle will be scrapped if its marginal driving costs are too high.
- Most scrappage in this model from discrete costs
  - Sudden repair
    - Accident or malfunction
  - Registration
  - Insurance

Responses to previous years reviewer comments

- This is the first year that the project has been reviewed.

Remaining Challenges and Barriers

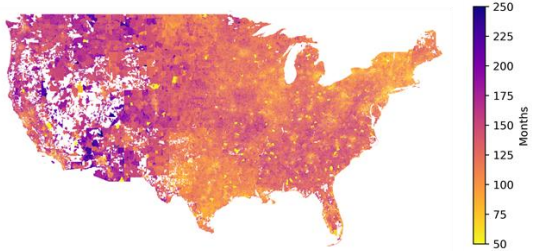
- Vehicles typically have many owners throughout their life, complicating assessments of single vehicles.
- Alternative fuel powertrains, especially electricity- or hydrogen-powered, may have special constraints on driving behavior because of fueling availability.
- While light-duty vehicles are 95% of the total vehicles registered on the road, they only use 30% of the fuel (Davis and Boundy, 2021 – VAN016). Better understanding of usage for medium- and heavy-duty vehicles is necessary for calculating energy use and emissions.
- Vehicle travel was drastically different in 2020, and forecasts of future travel are uncertain.
- Data on vehicle operation and ownership is difficult to find for analysis.

Any proposed future work is subject to change based on funding levels.

Proposed Future Research

- Development of publications and presentations based on findings
  - Variations in VMT as a function of vehicle and household characteristics planned for TRB Annual Meeting submission in July
  - Variations in scrappage as a function of vehicle and household characteristics planned for report in September
- Shift to deeper study of medium/heavy-duty vehicles
  - Most VMT data is out of date, but the Vehicle Inventory and Use Survey (VIUS) will be updated over the next two years
- Better understanding of changes in vehicle ownership throughout its life
  - Vehicle age is lowest in the suburbs, and highest in rural areas

Average age of crossover + sport utility vehicles (CUV/SUV) by zip code



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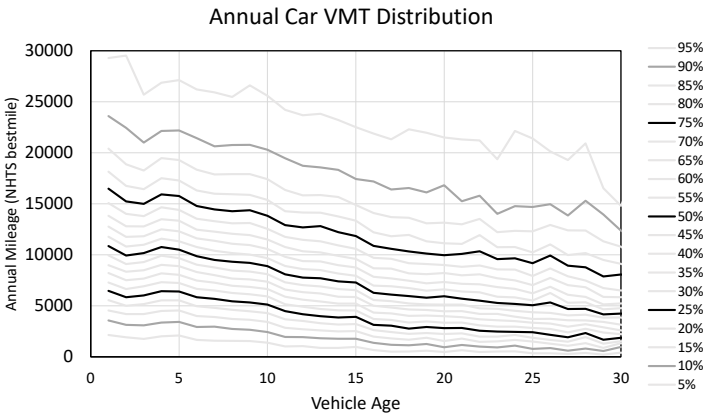
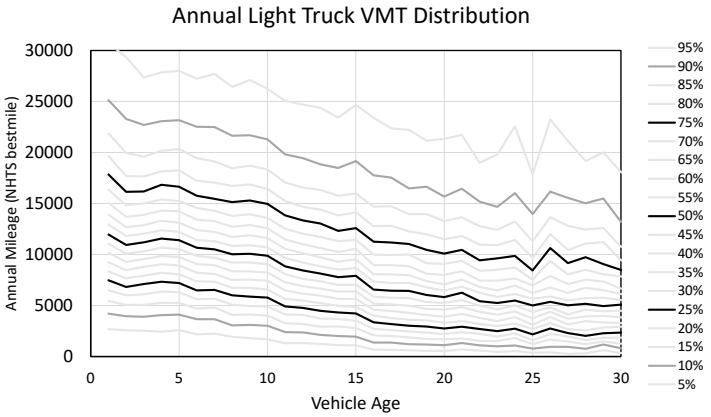
Collaboration and Coordination with other Institutions

- Linkage with other national lab researchers through VTO's Total Cost of Ownership project (VAN038)

- Results will be shared publicly as available. The information from this project would have several likely audiences.
  - This research would be useful for EERE program managers who are looking to understand technical requirements and potential markets for new technologies
  - Data can be used in vehicle choice models as created by other national labs or other agencies
  - Vehicle driving estimates and registration/survivability data can be linked with vehicle emissions data to understand distributions of local criteria air pollutants (especially from older vehicles and in disadvantaged communities)

Summary

- Understanding of vehicle usage (both driving distance and vehicle scrappage) is important for quantifying cost of driving, total vehicle emissions, and comparing different vehicle technologies
- Vehicles are not used homogenously, so it is important to account for variations
  - Differences by vehicle type, geography, fuel economy, powertrain
- Increased vehicle travel can make alternative fuel vehicles with lower operating costs but higher purchase costs more cost-effective, which can have a magnified impact for reducing fuel consumption or emissions